APPENDIX L: THROUGH-THE-WALL PRODUCTS

L.1 INTRODUCTION

Some residential unitary products are designed primarily as replacement products to fit within an existing building space with fixed dimensions. The fixed space, which might be either an interior enclosure, a part of the building's envelope, or both, can constrain the product's ability to improve efficiency using the same options available to products that do not face the same constraints, particularly increasing heat exchanger surface. Section 4.6 of the Engineering Analysis chapter of this TSD provides additional information on these space-constrained products which are also known as niche-products.

Products that install through an exterior wall are particularly susceptible to those constraints since they must exchange outdoor air through a single surface and fit within an existing wall opening with fixed dimensions that can be costly to modify. These products are termed Through-the-Wall (TTW) equipment. Two distinct versions of TTW products are identified: the condensing unit of a split-system air conditioner or heat pump; and a single-package air conditioner or heat pump. The purpose of this appendix is to provide a detailed description of the engineering methodology and results used to estimate the cost of achieving efficiency improvements in TTW products and the consumer economic analyses resulting from those improvements. The engineering analysis is presented in Section L.2 and the consumer economic analysis is presented in Section L.3.

L.2 ENGINEERING ANALYSIS

The engineering analysis for TTW products consisted of the purchase and evaluation of three common TTW units to identify efficiency improvement opportunities and estimate the manufacturing cost and retail price impacts of implementing those efficiency improvements. We evaluated three through-the-wall (TTW) products from two manufacturers as shown in Table L.2.1. The products include samples that the manufacturers identified as being the most constrained (2.5 tons cooling) as well as one sample that is a prevalent model but is less constrained (1.5 tons cooling). We evaluated two split systems (SAC 1.5 Ton and SAC 2.5 Ton) and one packaged system (PAC). Along with the split TTW condensers, we obtained the matching split fancoil. However, since producers of split TTW condensers do not typically design or specify their own fancoils, we did not consider possible improvements to the fancoil as part of our analysis.

The purpose of our evaluations was to estimate the manufacturing cost impacts of achieving performance improvements (as measured by SEER) in the range of 10 to 30 percent. This range of performance improvement corresponds to increasing SEER from 10 to between 11 and 13. Our evaluations included both laboratory tests and spreadsheet analyses. We did not evaluate any heat pumps, so we did not attempt to evaluate possible improvements in Heating Seasonal Performance Factor (HSPF) ratings. However, we believe that the HSPF-SEER relationship expressed in Section

4.8.1 of this TSD based on examination of all available residential unitary heat pumps also applies to TTW products.

Table L.2.1 TTW Products Evaluated

Manufacturer	Description	Published SEER	Short-Hand Designation
A	1.5 ton air-conditioning condensing unit	10.0	SAC 1.5 Ton
A	2.5 ton air-conditioning condensing unit	10.0	SAC 2.5 Ton
B	2.5 ton packaged air conditioner with gas-fired heater[1]	9.7	PAC

1) We did not include the gas-fired heater in our manufacturer-cost analysis.

L.2.1 Physical Characteristics of Baseline Products

Baseline products are those unmodified products listed in Table L.2.1 as we received them from the distributors. Table L.2.2 describes the key components we observed in the baseline products.

Table L.2.2 Key Components of TTW Products

Component	SAC 1.5 Ton	SAC 2.5 Ton	PAC
Compressor	Reciprocating (10.7 EER)	Reciprocating (10.9 EER)	Scroll (10.9 EER)
Condenser Air Mover	Forward-Inclined Blower	Forward-Inclined Blower	Propeller Fan
Condenser Motor	¼ Hp, 1140 RPM, PSC, 67.1% Efficiency	¼ Hp, 1140 RPM, PSC, 67.1% Efficiency	1/4 Hp, 1075 RPM, 60% Efficiency
Condenser Coil	3/8" rifled-tube, 3 rows deep by 17 tubes high, lanced fin, 16 fpi, 26.5" by 16.5" face	3/8" rifled-tube, 4 rows deep by 17 tubes high, lanced fin, 16 fpi, 26.5" by 16.6" face	3/8" rifled tube, 4 rows deep by 20 tubes high, single-sine-wave fin, 18 fpi, 24.0" by 20.0" face
Expansion Device	--	--	Capillary Tubes (4 in parallel)
Evaporator Air Mover	--	--	Confidential
Evaporator Fan Motor	--	--	1/3 Hp, 1120 RPM, 3 speed, 63% Efficiency
Evaporator Coil	--	--	3/8" rifled-tube, 4 rows deep by 16 tubes high, single-sine-wave fin, 14 fpi, 24.0" by 16.0" face

L.2.2 Modeling TTW Efficiency

To serve as a basis for our analysis of possible efficiency improvements, we developed spreadsheet models for each TTW product based on the compressor manufacturers' performance maps, generalized fan performance curves, and available test data (including detailed data from performance certification tests). The compressor manufacturer's performance maps were curve fit using polynomial equations for cooling capacity, compressor power, and refrigerant mass-flow rate for each compressor. We estimated SEER using the compressor performance map and condenser performance characteristics inferred from results of Test B of the SEER test procedure.[a] Based on the condenser blower power draw (from the equipment manufacturer) and total power draw (from Test B), we determined compressor power draw. Using the compressor performance map at a 45°F evaporating temperature, we determined the condensing temperature that best matched the compressor power draw and the Test B cooling capacity.

Condenser heat rejection is equivalent to the sum of evaporator capacity and compressor power draw, less heat loss from the compressor shell and the discharge line. Using the evaporator capacity (from Test B), the compressor power draw, and the assumed compressor shell and discharge line heat loss, we calculated condenser heat rejection.

We characterized the performance of outdoor blowers and fans using three parameters: pressure coefficient, flow coefficient, and specific speed. We modeled the SAC blowers using published impeller data for wheel sizes ranging from 4 in. to 8 in. in diameter. We modeled the PAC condenser fan using published propeller fan data for diameters from 16 in. to 20 in. We calculated the three parameters for each blower/fan size and type. We then correlated pressure and flow coefficients as a function of specific speed. These correlations allowed us to evaluate the performance of any size blower or fan at any flow rate and static pressure.

Using a commercially available heat exchanger sizing program[b], we estimated the pressure drop through the condenser. We approximated the balance of condenser-air static pressure loss based on each unit's specific blower/fan power draw (supplied by the equipment manufacturer) and performance curve. The pressure loss associated with the velocity pressure is twice the velocity head.

Based on condenser heat rejection, condenser airflow (either from the equipment manufacturer or a different airflow selected for analysis), and the air temperature entering the condenser (82°F for Test B), we calculated the air temperature leaving the condenser. Based on the condensing temperature and the entering and leaving air temperatures, we calculated the condenser log mean temperature difference (LMTD).

We assumed that the condenser LMTD remains roughly constant as condenser airflow rate changes. We used the compressor performance map iteratively to find a condensing temperature that resulted in roughly matching the target LMTD. We then calculated SEER using:

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[a] See *Code of Federal Regulations – Energy*; Office of the Federal Register, National Archives and Records Administration; January 1, 1999 revision; Subpart B; Appendix M.

[b] *Super Radiator Coil Selection Programs*, Version 1.71G; Super Radiator Coil; April 17, 1998.

- 365 W evaporator power draw per 1000 cfm through the evaporator and 400 cfm/ton cooling capacity (from the SEER test procedure);
- Condenser blower/fan power draw from a) the manufacturer, if condenser airflow rate is not varied, or b) the blower/fan correlations described above, if condenser airflow rate is varied; and
- A Degradation Coefficient (C_D) of 0.25 (from the SEER test procedure).[c]

Using this analytical approach, we predicted the performance of the equipment we evaluated and compared it to the published performance for each unit (see Table L.2.3). Predicted performance fell within 11 percent of actual performance, which is acceptable given the degree of simplification inherent in our approach. To reduce the effects of the disparities in baseline performance predictions, we express any predicted efficiency improvements as percentages relative to the manufacturers' published baseline SEER ratings rather than as absolute SEER adders.

Table L.2.3 Comparison of Published and Calculated Performance for Baseline Units

	SAC 1.5 Ton	SAC 2.5 Ton	PAC
Calculated SEER	9.79	9.21	10.76
Published SEER	10.0	10.0	9.7
Percent Difference	- 2.1%	- 7.9%	+ 10.9%

L.2.3 Design Options

To analyze the cost and efficiency impacts of modifications to the design or components of the baseline equipment, we utilized the "design option" approach. In this approach, we analyze individual options and assess their impacts on system efficiency, rather than analyzing system efficiency and drawing conclusions regarding the design options utilized to attain an efficiency level.

L.2.3.1 General Approach to Evaluating Design Options

We focused our evaluation on component changes and other performance improvement options that are:

- Apparent to a typical experienced design engineer and manufacturer;
- Compatible with current manufacturing processes;
- Readily available from suppliers;
- Moderate in manufactured cost impact; and
- Consistent with the physical size constraints for these products (i.e., do not increase overall package dimensions).

Table L.2.4 lists the performance improvement options considered. Each option is discussed

[c] A Degradation Coefficient of 0.25 corresponds to a Part-Load Performance Factor (PLF(0.5)) of 0.875.

further in Section L.2.3.2.

Table L.2.4 Performance Improvement Options Evaluated/Recommended

Option	SAC 1.5 Ton		SAC 2.5 Ton		PAC	
	Eval.	Rec.	Eval.	Rec.	Eval.	Rec.
Reduce Cabinet/Panel Air Leakage	X	X	X	X	X	
Dual Condenser Blowers[1]	X	X	X	X		
Increase Condenser Blower Outlet Area[1]	X		X			
Increase Condenser Airflow Rate	X	X	X	X	X	X
Improve Condenser Airflow Distribution	X		X		X	
Reduce Condenser Air Recirculation	X		X		X	
Higher-Efficiency Compressor	X	X	X	X	X	X
Mount Condenser Fan Above Condenser[2, 3]					X	X
Mount Dual Fans Above Condenser[2,4]					X	
Taller Condenser[5]					X	
Higher-Efficiency Condenser Fan Motor					X	X
Improve Evaporator Airflow Distribution[6]					X	X
Improve Evaporator Refrigerant Distribution					X	

1) Mutually exclusive options.
2) Mutually exclusive options.
3) Mounting the fan above the condenser should improve condenser airflow in the PAC unit, but we did not attempt to quantify the benefit or take credit for it in our analysis.
4) The only benefit of dual condenser fans is to allow more space for a taller condenser.
5) Taller condensers were not evaluated for the SAC units due to space constraints.
6) Modifying the design of the air-filter-mounting bracket may improve evaporator airflow distribution in the PAC unit, but we did not attempt to quantify the benefit or take credit for it in our analysis.

Emerging technologies were not considered because they do not meet the criteria listed above for ease of implementation and moderate cost impact. Manufacturers of mainstream residential air-conditioning products can achieve performance levels at or above those attainable by TTW equipment without employing these options. Therefore, we did not consider it appropriate to consider performance levels that would require use of emerging technologies for TTW products.

Some performance-improvement options were ruled out based on simple inspection or physical size constraints. Others required a combination of laboratory testing and analysis to evaluate. We did not attempt to demonstrate experimentally that the recommended design changes would result in the estimated performance improvements.

In the discussions below, we provide only brief discussions of the options not recommended, but provide a more thorough discussion of options that we recommend (i.e., that meet the criteria of being relatively easy to implement and of moderate cost impact.)

L.2.3.2 Discussion of Individual Design Options

L.2.3.2.1 Reduce Cabinet/Panel Air Leakage

Residential air-conditioning products generally incorporate sheet metal parts for cabinets, access panels, dividers (for example, between the hot and cold sides of a packaged unit), fan shrouds, blower housings, ducts, etc. Product design, dimensional tolerances on sheet metal parts, sealing techniques, and assembly techniques, and other factors determine the extent to which air can bypass heat exchangers, leak into or out of ducts, and/or recirculate around air movers. All of these potential air-leakage paths can reduce performance, and eliminating significant air-leakage paths can be a very cost-effective way to improve performance.

The air-leakage tests performed on each unit are discussed in Sections L.2.3.2.1.1 through L.2.3.2.1.3 below, and results are presented in Section L.2.3.2.1.4.

L.2.3.2.1.1 Air Leakage in SAC 1.5 Ton Unit

Upon inspection of the SAC 1.5 Ton unit, we found some obvious airflow leakage paths, including:

- Back access panel seal with cabinet;
- Knockouts for refrigeration piping and electrical wiring;
- Blower housing mount; and
- Excessive gap between blower wheel and blower housing.

To assess the performance penalty associated with eliminating most of the major leakage paths, we measured the total airflow through the unit as received, and again after sealing leakage paths with silicone rubber caulk and duct tape. We then estimated the impact on system performance associated with the increase in condenser airflow. We did not attempt to reduce the gap between the blower housing and blower wheel, so any improvement associated with this would be in addition to our estimate.

We conducted the total airflow tests with no load on the condenser. We used a 12” x 12” vortex-shedding flow meter, connected to the unit’s condenser air inlet with transition ductwork. We used sections of straight duct both upstream and downstream of the flow meter as recommended by the flow-meter manufacturer. We recorded airflow measurements for 3 to 5 minutes and averaged the results. We repeated each test three times, then averaged the three results for a final average flow rate.

Since we suspected that the back panel and the piping/wiring cutouts were responsible for most of the leakage, we repeated the tests with no sealing in these areas (referred to as the partially sealed test).

The results of these tests are shown in Section L.2.3.2.1.4 below.

L.2.3.2.1.2 Air Leakage in SAC 2.5 Ton Unit

The SAC 2.5 Ton unit exhibited similar leakage paths, except that the unit we received had been factory sealed (using a silicone rubber caulk) around the blower housing mount. We performed total air-flow tests as outlined above for the SAC 1.5 Ton unit, except that we didn’t perform the partially sealed test as it would have been no different than testing the unit as received.

We do not know whether the manufacturer uses silicone rubber caulking on all 2.5 ton units and none of the 1.5 ton units, whether they caulk any unit when in their judgement its warranted, or whether they have some other basis for use of caulk.

L.2.3.2.1.3 Air Leakage in PAC Unit

In our judgement, the PAC unit is designed and manufactured with good attention to airflow leakage, consistent with normal practice for residential air-conditioning products. While there may be room for minor improvements (such as a small leak path around the evaporator blower), we doubt significant performance improvement would result. We tested the PAC unit as received, consistent with the procedure outlined above for the SAC units. We did not, however, attempt to seal leakage paths and retest.

L.2.3.2.1.4 Results of Air-Leakage Evaluation

Table L.2.5 lists the results of the total airflow tests. Obviously, the approach we used to measure airflow introduces significant pressure losses that will not be present in installed units. However, we used the test results to calculate a percentage change in airflow only, and we did not use the absolute results in evaluating impact on performance.

Table L.2.5 Total Airflow Test Results

Unit	Flow Rate as Received[1]	Flow Rate when Partially Sealed[2]	Flow Rate when Fully Sealed	Average Increase in Flow Rate
SAC 1.5 Ton	690 cfm 700 cfm 690 cfm	710 cfm 715 cfm 705 cfm	730 cfm 725 cfm 730 cfm	5%
SAC 2.5 Ton	695 cfm 700 cfm 700 cfm	--	755 cfm 750 cfm 750 cfm	8%
PAC	1140 cfm 1160 cfm 1160 cfm	--	--	--

1) The experimental apparatus used to measure airflow places additional resistance in the airflow path. Therefore, these measurements do not correspond to normal condenser airflow as installed.

2) The back panel (including cutouts for piping and wiring) was left unsealed for this test.

We then estimated the system performance impact associated with increased condenser airflow using the analytical approach described in Section L.2.2 (but assuming constant blower power draw). We conducted this analysis for the SAC 2.5 Ton unit only, and assumed the performance improvement estimates (as percentages) would apply to the SAC 1.5 Ton unit as well. We investigated condenser airflow-rate increases ranging from 0 to 20 percent (see Table L.2.6).

Table L.2.6 Estimated Performance Improvement Associated with Increased Condenser Airflow (at no Increase in Power Draw)

Percent Increase in Airflow	0%	5%	10%	20%
Evaporating Temperature	45°F	45°F	45°F	45°F
Condensing Temperature	116.4°F	114.8°F	113.6°F	111.3°F
System Performance Multiplier[1]	--	1.02	1.04	1.07

1) Performance relative to normal airflow (0 percent increase). Assumes no increase in condenser air-mover power draw.

Table L.2.7 summarizes the estimated system performance improvements associated with reducing air-leakage paths. Again, these estimates do not include improvements associated with reducing clearances between the blower wheel and blower housing. Although it does not impact SEER, the air leakage through the back panel and cutouts may impact installed performance by a greater margin than reflected in Table L.2.6. For units installed in a conditioned space, conditioned air will leak through the back panel and be discharged outdoors, resulting in increased infiltration losses in the building. These losses would not impact the SEER rating, but certainly could impact actual energy consumption in the field.

Table L.2.7 Estimated System Performance Improvements Associated with Reduced Air Leakage

	SAC 1.5 Ton	SAC 2.5 Ton
Increase in Airflow Rate[1]	5%	8%
System Performance Multiplier[2]	1.02	1.03

1) From Table L.2.5
2) From Table L.2.6, interpolating for the SAC 2.5 Ton unit.

L.2.3.2.2 Dual Condenser Blowers

The SAC 1.5 Ton and SAC 2.5 Ton units discharge air through a 4.5” by 28.5” rectangular opening above the condenser. Both units have a blower housing discharge opening (4.5” by 9”) that is much smaller than the available space. A larger blower housing discharge area would lower the discharge velocity (keeping total airflow constant), thereby lowering pressure losses associated with the abrupt expansion at the blower exit. One way to achieve a larger blower discharge area is to use two blowers. A common motor having two shafts can drive the two blowers.

We used the general analytical approach described in Section L.2.2 to evaluate dual blowers. Table L.2.8 lists the estimated system performance impact of using dual blowers in the SAC units.

Table L.2.8 Estimated System Performance Improvements Associated with Dual Blowers

	SAC 1.5 Ton	SAC 2.5 Ton
Baseline[1] Airflow	900 cfm	1000 cfm
Baseline[1] Motor	1/2 hp	3/4 hp
Dual Blower Airflow	1000 cfm	1100 cfm
Dual Blower Motor	1/2 hp	3/4 hp
System Performance	**1.04**	**1.04**

1) "Baseline" refers to the current design employing a single blower.

L.2.3.2.3 Increase Condenser Blower Outlet Area

Another way to effect lower expansion losses at the blower exit for the SAC units is to simply select a blower having a larger discharge area, but that is otherwise suitable for the application. The blowers we found that had larger discharge areas exceeded the height available (4.5 inches). Suitable blowers may be available, or they certainly could be developed, but it is likely that the associated performance improvements would be similar to those estimated for dual blowers in Section L.2.3.2.2. Therefore, we did not consider this option further.

L.2.3.2.4 Increase Condenser Airflow Rate

Using the analytical approach described in Section L.2.2, we evaluated the system performance impacts of changing condenser airflow rate. The results of our analytical modeling suggest that, while the performance benefits may be modest, the condenser airflow may not be optimized in any of the three units. We did not consider noise levels, however, and increasing condenser airflow will, in general, increase noise. Table L.2.9 lists the estimated performance multipliers associated with optimizing condenser airflow.

Table L.2.9 Estimated System Performance Improvements Associated with Optimized Condenser Airflow

	SAC 1.5 Ton	SAC 2.5 Ton	PAC
Baseline Condenser Airflow Rate	700 cfm	900 cfm	1200 cfm
Baseline Motor	1/3 hp	1/2 hp	1/2 hp
Optimized Condenser Airflow Rate	900 cfm	1000 cfm	1400 cfm
Required Motor	1/2 hp	3/4 hp	3/4 hp
System Performance Multiplier	**1.03**	**1.02**	**1.01**

L.2.3.2.5 Improve Condenser Airflow Distribution

We measured the condenser airflow distribution (at the condenser inlet) in each unit using a digital anemometer ("hot-wire" probe). We rotated the probe to obtain the maximum reading at each measurement point. We divided the face of each condenser into a grid, and measured air velocity at the center of each grid section, reading a three-to-five second average. We repeated each test three times and averaged the results. We normalized the results to the average velocity reading over the face of the condenser. There was no load on the condensers during the tests. Tables L.2.10 to L.2.12 show the test results.

Table L.2.10 SAC 1.5 Ton – Condenser Airflow Distribution[1]

1.61	0.66	0.64	0.42	1.43
1.46	0.53	0.57	0.34	0.81
1.91	0.82	0.94	0.64	1.16
1.68	1.01	1.20	0.56	1.63

1) Measurements are normalized to the average velocity. The table is oriented as if facing the upstream face of the condenser. Each grid section is 5.33" by 4.125". The condenser face is 26.5" long by 16.5" high.

Table L.2.11 SAC 2.5 Ton – Condenser Airflow Distribution[1]

1.15	0.19	0.38	0.36	0.93
1.66	0.60	0.49	0.37	0.71
1.65	1.12	1.18	1.13	1.27
1.48	1.56	1.48	0.48	0.80

1) Measurements are normalized to the average velocity. The table is oriented as if facing the upstream face of the condenser. Each grid section is 5.33" by 4.125". The condenser face is 26.5" long by 16.5" high.

Table L.2.12 PAC – Condenser Airflow Distribution[1]

0.95	1.04	1.09	1.13	0.96	0.87
1.08	1.10	1.12	1.10	1.03	0.94
1.06	1.08	1.05	1.15	1.03	0.95
0.98	1.00	1.01	1.10	0.96	0.92
0.97	0.90	0.93	1.02	0.81	0.68

1) Measurements are normalized to the average velocity. The table is oriented as if facing the upstream face of the condenser. Each grid section is 4" by 4". The condenser face is 24" long by 20" high.

While there is some airflow maldistribution in the SAC units (probably due to the blower housing blocking part of the condenser and the orientation of the blower inlets), improving airflow distribution can be difficult, especially given the tight packaging constraints. We did not include improved condenser airflow distribution as a performance-improvement option.

L.2.3.2.6 Reduce Condenser Air Recirculation

Each of the TTW products evaluated exhausts condenser air directly above the inlet to the condenser – which is probably the only practical way to package a TTW product. In the case of the PAC unit, louvers covering the exhaust air plenum actually serve to direct air downward, in the path of the air entering the condenser. (Presumably, the louvers are angled this way to divert rain.) Given this configuration, some of the discharge air could become be drawn into the condenser inlet, increasing the average inlet air temperature above ambient temperature.

We tested each unit using simple flow-visualization techniques to see if there was evidence of condenser-air recirculation. While our test method was not quantitative, we judged the recirculation effects to be minor for all three units. Therefore, we did not include reduced condenser-air recirculation as a performance-improvement option.

L.2.3.2.7 Higher-Efficiency Compressor

We used the analytical approach described in Section L.2.2 to evaluate the performance impacts of using higher-efficiency compressors. First, we identified a compressor having physical dimensions and a nominal cooling capacity similar to the baseline (current) compressor, but having a higher rating-point efficiency. We approximated the performance of each higher-efficiency compressor by simply multiplying the performance predicted for the baseline compressor by the ratio of the rating-point efficiencies (EERs) for the baseline and higher-efficiency compressors. Table L.2.13 lists the results.

Table L.2.13 Estimated System Performance Improvements Associated with Higher-Efficiency Compressors

	SAC 1.5 Ton	SAC 2.5 Ton	PAC
Baseline Compressor Manufacturer	A	A	B
Baseline Compressor EER[1]	10.7	10.9	10.9
Higher-Efficiency Compressor	A	A	A
Higher-Efficiency Compressor EER[1]	11.1	11.5	11.5
System Performance Multiplier[2]	**1.02**	**1.05**	**1.04**

1) Compressor EER at ARI rating point.
2) System performance multiplier is **not** the ratio of compressor EERs, but rather the ratio of system SEERs.

L.2.3.2.8 Mount Condenser Fan above Condenser

We observed in the PAC unit that the condenser fan (mounted immediately downstream of the condenser) discharges against the wall separating the indoor and outdoor portions of the unit. This probably results in pressure losses that may be avoided by mounting the condenser fan above the condenser, at the point the condenser air is discharged from the unit. While we recommend consideration of this design change, we did not attempt to quantify its benefit, nor did we take credit for it in our performance improvement estimates.

L.2.3.2.9 Mount Dual Fans Above Condenser

This is a variation on mounting a single condenser fan above the condenser in the PAC unit. The only reason for considering dual fans (mounted side by side) is to allow additional room for a taller condenser (see discussion in Section L.2.3.2.10). However, we judged that sufficient space already exists above the condenser to mount a single fan and still increase condenser height by a significant amount (up to 20 percent). While we didn't perform an analysis, we judged that any additional increase in condenser height permitted by dual fans is unlikely to improve performance commensurate with the cost premium (for dual fans and taller condenser) and, therefore, did not include it as a performance-improvement option.

L.2.3.2.10 Taller Condenser

The tight packaging of the SAC units precludes use of a condenser having increased face area without increasing overall unit dimensions. The SAC condensers are already three and four rows deep (for the SAC 1.5 Ton and SAC 2.5 Ton units, respectively) with significant airside pressure drop. Increasing condenser depth further will likely provide diminishing returns. However, the PAC unit, which is much taller than the SAC units, provides ample space to increase condenser height without impacting overall unit dimensions.

We used the approach outlined in Section L.2.2 to analyze a 20 percent increase in condenser height in the PAC unit. This increase is consistent with the maximum height increase we judged to be feasible while still permitting mounting of the condenser fan above the condenser (as discussed in Section L.2.3.2.8). We maintained a constant condenser face velocity, resulting in a 20 percent increase in condenser airflow (and an associated increase in condenser fan power draw). Our analysis resulted in a system performance multiplier of 1.02 associated with a 20 percent taller condenser.

L.2.3.2.11 Higher-Efficiency Condenser Fan Motor

Each SAC unit uses a 67.1 percent (nominal) efficient, ¼ Hp, Permanent Split Capacitor (PSC) motor. This is a reasonably high efficiency for fractional horsepower motors without resorting to expensive electronically commutated DC motors. The PAC unit, however, uses a 60 percent (nominal) efficient, ¼ Hp motor. We evaluated substituting a 67 percent efficient fan motor for the 60 percent efficient motor in the PAC unit, using the analytical approach outlined in Section L.2.2. The resulting system performance multiplier is 1.01.

L.2.3.2.12 Improve Evaporator Airflow Distribution

We measured the evaporator airflow distribution (at the evaporator inlet) in the PAC unit, using a test procedure similar to that described in Section L.2.3.2.5 for condenser airflow distribution. Table L.2.14 shows the test results.

Table L.2.14 PAC – Evaporator Airflow Distribution[1]

1.13	0.70	0.82	0.84	0.83	0.87
1.42	1.21	1.14	1.03	1.04	0.96
1.24	1.27	1.21	1.17	1.26	1.01
0.82	0.50	0.39	1.37	1.10	0.75

1) Measurements are normalized to the average velocity. The table is oriented as if facing the upstream face of the evaporator. Each grid section is 4” by 4”. The evaporator face is 24” long by 16” high. The air filter was removed during the tests.

The results show some maldistribution of airflow, especially in the lower left section. A bracket used to support the air filter is a likely contributor to low airflow in the lower left section. Redesign of this bracket is suggested. The evaporator is also mounted at an angle relative to the airflow path, and the airflow path takes right-angle bends just upstream and just downstream of the evaporator. With the physical constraints of the package, it may be difficult to improve airflow distribution significantly. We, therefore, did not include it as a performance-improvement option.

L.2.3.2.13 Improve Evaporator Refrigerant Distribution

The PAC evaporator has eight parallel refrigerant circuits. Poor refrigerant distribution among the circuits (caused, for example, by evaporator airflow maldistribution or uneven refrigerant distribution to the circuits by the expansion device) could pose a significant system performance penalty. We attempted to infer the nature of refrigerant distribution by measuring the superheat at the exit of each refrigerant circuit. Unfortunately, the header design prevented making accurate temperature measurements on individual circuits at their exits. We, therefore, settled for measuring temperatures at exit of the seventh pass (of eight passes) on each circuit. We also measured refrigerant temperature entering the fourth pass of each circuit (to provide refrigerant saturation temperature), and the exiting refrigerant temperature downstream of the header (to determine overall superheat) . We used wall-mounted, Type T thermocouples for all temperature measurements.

Given the limitations of our test procedure, we cannot conclude that no refrigerant maldistribution was present. However, the test results did not show evidence of gross maldistribution. Also, the evaporator and expansion device design suggest that reasonable measures were taken to prevent maldistribution of refrigerant. We did not include improved evaporator refrigerant distribution as a performance-improvement option.

L.2.4 Estimated Manufactured-Cost Impacts

As part of our previous work in support of the Notice of Proposed Rulemaking for central air conditioners and heat pumps,[d] we developed a manufactured-cost model for a 3-ton air conditioner based on reverse engineering. We expanded this model to include the three TTW products. The key assumptions employed include:

- Annual production volumes of 10,000 units (down from 100,000 in the original model);
- TTW manufacturers out-source condenser and evaporator fabrication (consistent with current practice for SAC and PAC);
- SAC out-sources all sheet-metal fabrication, paying a 50 percent vendor markup;
- PAC fabricates sheet-metal parts in house;
- Labor, packaging, and enclosure-material costs can be scaled, based on nominal cooling capacity, from costs for 3-ton central air conditioners; and

[d] *Technical Support Document for the Notice of Proposed Rulemaking for Central Air Conditioners and Heat Pumps*; 65 FR 59950; October 5, 2000

- TTW manufacturing is seasonal. We assumed that plant capacity is double the average production volume to allow for fluctuations in demand. (This plant capacity assumption has little impact on manufactured costs due to the relatively low equipment utilization rates associated with the production volumes.)

We updated cost estimates for all components costing more than $3, including compressors, condensers, evaporators, motors, fans/blowers, and controls. The TTW model accounted for about 90 percent of the total unit cost. We based cost estimates for major components on actual vendor quotations and estimated other component costs.

Table L.2.15 compares the baseline manufactured-cost estimates to those approximated by backing out distribution-chain markups from wholesale equipment prices. The agreement is generally very good – well within the estimated accuracy of the TTW cost model (+/- 15 percent).

Table L.2.15 Comparison of Baseline Estimated Manufactured Cost and Derivation of Retail Price Estimate

	SAC 1.5 Ton	SAC 2.5 Ton	PAC
Wholesale Price Paid	$697.50	$892.50	$1495.00
Manufacturer Markup (Multiplier)[1]	1.23		
Distributor Markup (Multiplier)[1]	1.37		
Wholesale Price Less Markups	$414	$530	$887
Estimated Cost Credit for Heating Package[2]	--	--	$50
Adjusted Wholesale Price Less Markups	$414	$530	$837
ADL Reverse Engineering Model Prediction	**$443**	**$513**	**$887**
Difference	6.6%	-3.2%	5.6%
Estimated Adder for Indoor Unit[3]	$60	$73	--
Markup (Mfr cost to Retail)[4]	2.42		
Estimated Retail Price	**$1221**	**$1422**	**$2153**

1) Source: *Technical Support Document for the Notice of Proposed Rulemaking for Central Air Conditioners and Heat Pumps*; 65 FR 59950; October 5, 2000; Pp. 4-19 and 4-20.
2) The PAC wholesale price includes a gas-heating package. We deducted the estimated manufactured cost of the heating package to estimate the cost without a heating package.
3) Based on matched fancoil cost estimates derived from the reverse engineering analysis performed on mainstream products as detailed in Appendix B and Appendix C.
4) See Appendix D.

Table L.2.16 lists estimated manufactured-cost adders (increases in the baseline cost estimates listed in Table L.2.15) for the performance-improvement options judged to have the most promise.

Table L.2.16 Estimated Manufactured-Cost Adders

Option	SAC 1.5 Ton	SAC 2.5 Ton	PAC
Reduce Cabinet/Panel Air Leakage	Materials & Labor +$3	Materials & Labor +$3	--
Dual Condenser Blowers	Difference between Motor *A* (1/4hp) and Blower *A* vs. Motor *B* (1/3 hp) and dual Blower *B* +$33	Difference between Motor *A* (1/4 hp) and single Blower *D* vs. Motor *C* (1/2 hp) and dual Blower *C* +$21	--
Increase Condenser Airflow Rate	Difference between Motor *A* (1/4 hp) and Blower *A* vs. Motor *B* (1/3 hp) and Blower *C* +$5	Difference between Motor *A* (1/4 hp) and Blower *D* vs. Motor *B* (1/3 hp) and Blower *D* +$7	Difference between Motor *D* (1/4 hp) and Motor *C* (1/2 hp) -$1[2]
Higher-Efficiency Compressor	Difference between Compressor *A* and Compressor *B* (11.1 EER) +$27[3]	Difference between Compressor *C* and Compressor *D* (11.5 EER) +$24[4]	Difference between Compressor *E* and Compressor *F* +$24[5]
Mount Condenser Fan Above Condenser	--	--	Assume no change in fan and no difference in mounting cost +$0
Higher-Efficiency Condenser Fan Motor	--	--	Difference between Motor *E* and Motor *A* +$14
20% Taller Condenser	--	--	Replace Heat Exchanger *A*(24" x 20") with one 20% taller +$30

1) Cost estimates are derived from list retail prices, and hence included larger markups than an OEM would normally pay. We cut the advertised prices by 40-60 percent as our estimate of the price the OEM would pay, depending on market volume of the exact component.
2) For this motor type, the larger ½ hp motors are made at higher production volumes than equivalent ¼ hp motors, and are thus slightly less expensive. This effect will fluctuate with market conditions.
3) Assumes cost of the 11.1 EER compressor is the same as for a comparable 11.0 EER model.
4) Assumes cost of the 11.5 EER compressor is the same as for a comparable 11.4 EER model.
5) Assumes cost of the 10.9 EER compressor is the same as for a comparable 10.9 EER model from a different manufacturer.

L.2.5 Summary of Performance-Improvement Options and Manufactured-Cost Impacts

Tables L.2.17 through L.2.19 summarize the recommended performance-improvement options and their respective manufactured-cost impacts for the SAC 1.5 Ton, SAC 2.5 Ton, and PAC units, respectively. For the range of performance-improvement options investigated, the system performance improvement is roughly proportional to the manufactured-cost impact. (This observation cannot, however, be extrapolated to further increases in system performance.) The tables provide strong evidence that TTW products can readily achieve 11 SEER, with the possible exception of the PAC unit. The PAC unit can readily achieve about a ten- percent improvement, consistent with the performance improvement associated with raising the requirement for non-heating TTW products from 10 SEER to 11 SEER.

Table L.2.17 SAC 1.5 Ton – Estimated Performance Improvement and Associated Manufactured-Cost Adder

Option[1]	Cumulative Performance Improvement		Cumulative Cost/Price Impact		
	Multiplier	SEER	Mfr Cost/ Percent		Retail Price[3]
Baseline Unit	1.00	10.0	$0	0.0%	$0
Reduce Cabinet/Panel Air Leakage[2]	1.02	10.2	$3	0.7%	$6
Increase Condenser Airflow Rate	1.05	10.5	$8	1.8%	$15
Dual Condenser Blowers	1.09	10.9	$41	9.3%	$79
Higher-Efficiency Compressor	1.12	11.2	$68	15.3%	$131

1) Options listed in the logical order of implementation.
2) Improvement in actual field performance may be greater due to reduced infiltration.
3) Based on a total markup 1.92 on incremental changes in cost. See Appendix D.

Table L.2.18 SAC 2.5 Ton – Estimated Performance Improvement and Associated Manufactured-Cost Adder

Option[1]	Cumulative Performance Improvement		Cumulative Cost/Price Impact		
	Multiplier	SEER	Mfr Cost/ Percent		Retail Price[3]
Baseline Unit	1.00	10.0	$0	0.0%	$0
Reduce Cabinet/Panel Air Leakage[2]	1.03	10.3	$3	0.6%	$6
Increase Condenser Airflow Rate	1.05	10.5	$10	1.9%	$19
Higher-Efficiency Compressor	1.09	10.9	$34	6.6%	$66
Dual Condenser Blowers	1.14	11.4	$55	10.7%	$106

1) Options listed in the logical order of implementation.
2) Improvement in actual field performance may be greater due to reduced infiltration.
3) Based on a total markup 1.92 on incremental changes in cost. See Appendix D.

Table L.2.19 PAC – Estimated Performance Improvement and Associated Manufactured-Cost Adder

Option[1]	Cumulative Performance Improvement		Cumulative Cost/Price Impact		
	Multiplier	SEER	Mfr Cost/ Percent		Retail Price[6]
Baseline Unit[2]	1.00	9.7	$0	0.0%	$0
Mount Condenser Fan Above Condenser[3]	1.00	9.7	$0	0.0%	$0
Improve Evaporator Airflow Distribution[4]	1.00	9.7	$0	0.0%	$0
Increase Condenser Airflow Rate[5]	1.01	9.8	($1)	-0.0%	($2)
Higher-Efficiency Compressor	1.05	10.2	$23	2.6%	$44
Higher-Efficiency Condenser Fan Motor	1.07	10.4	$37	4.2%	$71
Taller Condenser	1.09	10.6	$67	7.6%	$129

1) Options listed in the logical order of implementation.
2) This is the baseline SEER with the gas-heating package. Without the gas-heating package, the baseline SEER could be slightly higher.
3) Mounting the condenser fan above the condenser should reduce system pressure losses, but we did not attempt to quantify this benefit.
4) Modifying the design of the air-filter-mounting bracket may improve evaporator airflow distribution, but we did not attempt to quantify this benefit or take credit for it in our analysis.
5) The manufactured-cost impact is slightly negative due to differences in motor supplier sales volume.
6) Based on a total markup 1.92 on incremental changes in cost. See Appendix D.

L.3 LIFE-CYCLE COST ANALYSIS

The life-cycle cost (LCC) analysis for TTW products was accomplished by using the same spreadsheet models that were used for the general LCC analysis (refer to Chapter 5). But since TTW products are almost entirely used in multi-family residences, the LCC analysis for TTW products is conducted only on those central air-conditioned households in multi-family buildings. As defined by the 1997 Residential Energy Consumption Survey (RECS), multi-family households are those households that reside in apartments buildings with two or more units.

L.3.1 Inputs to the LCC Analysis

The LCC analysis for TTW products utilizes the same inputs as those used in the general LCC analysis (as described in Chapter 5) but with the following exceptions: 1) manufacturing cost estimates for baseline and standard-level TTW products are based on data presented earlier in this Appendix (Sections L.2.5 and L.2.6), 2) compressor replacement costs are based on costs specific to TTW products, and 3) annual energy consumption, equipment efficiency, and electricity price data are based only those central air conditioned households residing in multi-family residences.

L.3.1.1 Baseline and Standard-Level Manufacturing Costs

Tables L.3.1 through L.3.3 present the baseline and standard-level manufacturing costs for the three TTW units analyzed: SAC 1.5 Ton, SAC 2.5 Ton, and PAC. In addition to the manufacturing cost estimates, the consumer equipment price (i.e., retail price) and the total installed cost to the consumer are also are presented in each of the following tables. Manufacturing cost estimates are summarized from information presented earlier in tables L.2.15 through L.2.19. Consumer equipment prices and total installed costs are generated with the same markups, sales tax, and installation prices as used in the general LCC analysis (refer to Chapter 5 and Appendix D). Since the markups, sales tax, and installation prices are represented with probability distributions rather than single-point values, the consumer equipment prices shown in Tables L.3.1 through L.3.3 are *weighted-average* values.

Table L.3.1 SAC 1.5 Ton TTW Unit: Baseline and Standard-Level Weighted-Average Manufacturing Costs, Consumer Equipment Prices, and Total Installed Costs

SEER	Manufacturing Cost *1998$*	Consumer Equipment Price *1998$*	Total Installed Cost *1998$*
10	$503	$1,221	$2,500
10.2	$506	$1,227	$2,506
10.5	$511	$1,236	$2,515
10.9	$544	$1,300	$2,579
11.2	$571	$1,352	$2,631

Table L.3.2 SAC 2.5 Ton TTW Unit: Baseline and Standard-Level Weighted-Average Manufacturing Costs, Consumer Equipment Prices, and Total Installed Costs

SEER	Manufacturing Cost *1998$*	Consumer Equipment Price *1998$*	Total Installed Cost *1998$*
10	$586	$1,422	$2,701
10.3	$589	$1,428	$2,707
10.5	$596	$1,441	$2,720
10.9	$620	$1,488	$2,767
11.4	$641	$1,528	$2,807

Table L.3.3 PAC TTW Unit: Baseline and Standard-Level Weighted-Average Manufacturing Costs, Consumer Equipment Prices, and Total Installed Costs

SEER	Manufacturing Cost *1998$*	Consumer Equipment Price *1998$*	Total Installed Cost *1998$*
9.7	$887	$2,153	$3,520
9.8	$886	$2,151	$3,518
10.2	$910	$2,197	$3,564
10.4	$924	$2,224	$3,591
10.6	$954	$2,282	$3,649

L.3.1.2 Compressor Replacement Costs

As described in Chapter 5, Section 5.2.3.10, *Lifetime and Compressor Replacement Cost*, the LCC analysis assumes that a compressor needs to be replaced in the 14th year of the system's life. Tables L.3.4 through L.3.6 show the manufacturer cost, average consumer price, and the present value of the consumer price (discounted based on an average rate of 5.6%) for each of the three TTW units analyzed. It is important to note that the compressor replacement price is the price for the compressor only. The labor cost associated with the compressor's installation is assumed to remain constant as system efficiency increases.

Table L.3.4 SAC 1.5 Ton TTW Unit: Compressor Replacement Costs

Efficiency		**Consumer Price**	
SEER	**Manufacturer Cost**	In year replaced	Present Value
10	$102	$232	$108
10.2	$102	$232	$108
10.5	$102	$232	$108
10.9	$102	$232	$108
11.2	$170	$356	$166

Table L.3.5 SAC 2.5 Ton TTW Unit: Compressor Replacement Costs

Efficiency		**Consumer Price**	
SEER	**Manufacturer Cost**	In year replaced	Present Value
10	$128	$292	$136
10.3	$128	$292	$136
10.5	$128	$292	$136
10.9	$162	$353	$165
11.4	$162	$353	$165

Table L.3.6 PAC TTW Unit: Compressor Replacement Costs

Efficiency		**Consumer Price**	
SEER	**Manufacturer Cost**	In year replaced	Present Value
9.7	$179	$408	$190
9.8	$179	$408	$190
10.2	$202	$450	$210
10.4	$202	$450	$210
10.6	$202	$450	$210

L.3.1.3 Multi-Familiy Households: Annual Energy Use, Equipment Efficiency, and Electricity Prices

As noted earlier, because TTW products are almost entirely used in multi-family residences, the LCC analysis for TTW products is conducted only on those central air-conditioned households in multi-family buildings. Table L.3.7 summarizes the *weighted-average* input values for multi-family households and compares them to the *weighted-average* input values for all households in the 1997 RECS utilizing central air conditioners and heat pumps. Other than the sample size, multi-family households differ significantly from the overall sample in that the annual space-cooling energy use is significantly lower. Also, multi-family average and marginal electricity prices are both higher than those for the overall sample.

Table L.3.7 Comparison of Input Values for All Households and Multi-Family Households

Category	All Households	Multi-Family
Household Population Data		
Number of Households	1218	176
Sum of Weights	23,420,428	3,361,055
Percent of AC or HP Household Population	-	14.4%
***Weighted-Average* Annual Energy Use and Efficiency Data**		
Stock Space-Cooling Energy Use (kWh/yr)	2132	1361
Stock Space-Cooling Efficiency (SEER)	9.13	8.84
Baseline Space-Cooling Energy Use (kWh/yr)	1947	1203 [1]
***Weighted-Average* Electricity Prices**		
Average Electricity Price (¢/kWh)	8.90	9.49
Marginal Electricity Price (¢/kWh)	8.62	9.01

[1] Baseline energy use pertains to 10 SEER equipment. For 9.7 SEER baseline equipment the use is 1241 kWh/yr.

L.3.2 LCC Results

LCC results are presented for the three TTW units analyzed. Since the value of most LCC inputs are uncertain and are represented by a distribution of values rather than a single point-value, the LCC results will also be a distribution of values.

L.7.2.1 Baseline LCC

The first step in developing LCC results is to develop the baseline LCC. The baseline efficiency level is assumed to equal 10 SEER for SAC TTW units and 9.7 SEER for PAC TTW units. The baseline LCC for each TTW unit are represented by a distribution of values. The actual distributions are not shown here. But Table L.3.8 presents the mean, median, minimum, and maximum LCCs for the baseline efficiency level for each of the three TTW units analyzed.

Table L.3.8 Baseline LCC for TTW Units: Mean, Median, Min, and Max Values

Unit Type	Minimum	Median	Mean	Maximum
SAC 1.5 Ton	$2,330	$4,271	$4,576	$14,673
SAC 2.5 Ton	$2,387	$4,564	$4,867	$16,828
PAC	$3,227	$5,799	$6,001	$16,980

L.3.2.2 Change in LCC

The change in LCC results are presented as differences in the LCC relative to the baseline design. Similar to the baseline LCC, the LCC differences are depicted as a distribution of values. The primary results are presented as either a *frequency chart* showing the distribution of LCC differences with its corresponding probability of occurrence or a *cumulative chart* showing the cumulative distribution of LCC differences along with the corresponding probability of occurrence. These charts are not presented here. Rather, Tables L.3.9 through L.3.11 are provided summarizing the change in LCC from the baseline by percentile groupings (i.e., of the distribution of results) for each of the three TTW units analyzed. The mean and the percent of LCCs that are reduced for each standard-level are also shown.

As an example of how to interpret the information in Tables L.3.9 through L.3.11, the 10.2 SEER efficiency level for SAC 1.5 Ton is reviewed. The 10.2 SEER efficiency level in Table L.7.9 (row 1) shows that the maximum (zero percentile column) change in LCC is savings of $169. (Negative values are net savings.) For 90% of the cases studied (90^{th} percentile), the change in LCC is a cost of $1 or less. The largest increase in LCC is $7 ($100^{th}$ percentile). The mean change in LCC is a net savings of $17. The last column shows that 87% of the sample have reduced LCC (i.e., change in LCC less than or equal to zero).

Table L.3.9 Summary of LCC Results for SAC 1.5 Ton

Efficiency Level (SEER)	Change in LCC from Baseline Shown by Percentiles of the Distribution of Results (values in 1998$)												Percent of Households with reduced LCC
	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%	Mean	
10.2	$-169	$-44	$-29	$-21	$-15	$-11	$-7	$-4	$-2	$1	$7	$-17	87%
10.5	$-503	$-109	$-71	$-50	$-36	$-26	$-17	$-9	$-3	$4	$16	$-42	85%
10.9	$-658	$-128	$-64	$-29	$-6	$11	$26	$39	$50	$62	$112	$-15	44%
11.2	$-803	$-73	$5	$43	$69	$87	$103	$121	$142	$171	$312	$62	19%

Table L.3.10 Summary of LCC Results for SAC 2.5 Ton

Efficiency Level (SEER)	Change in LCC from Baseline Shown by Percentiles of the Distribution of Results (values in 1998$)												Percent of Households with reduced LCC
	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%	Mean	
10.3	$-296	$-68	$-45	$-34	$-25	$-19	$-14	$-9	$-6	$-2	$8	$-29	94%
10.5	$-450	$-103	$-66	$-45	$-33	$-22	$-13	$-6	$1	$7	$21	$-37	79%
10.9	$-745	$-107	$-45	$-14	$7	$23	$36	$47	$59	$75	$140	$-1	37%
11.4	$-939	$-171	$-78	$-30	$3	$27	$48	$67	$84	$103	$181	$-9	39%

Table L.3.11 Summary of LCC Results for PAC

Efficiency Level (SEER)	Change in LCC from Baseline Shown by Percentiles of the Distribution of Results (values in 1998$)												Percent of Households with reduced LCC
	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%	Mean	
9.8	$-114	$-30	$-21	$-17	$-14	$-11	$-9	$-7	$-6	$-5	$-2	$-15	100%
10.2	$-398	$-62	$-25	$-6	$7	$17	$25	$32	$39	$49	$89	$3	34%
10.4	$-535	$-85	$-32	$-5	$12	$27	$38	$48	$59	$71	$118	$6	32%
10.6	$-683	$-61	$4	$36	$59	$76	$90	$104	$116	$133	$209	$52	19%

L.3.2.3 LCC Results based on ±2% Threshold

The results in Tables L.3.9 through L.3.11 show the percent of households with reduced LCC. But considering that the baseline LCC for each product class is significantly greater than the LCC differences shown in Tables L.3.9 through L.3.11, it is more useful to demonstrate which consumers experience net LCC savings or costs within a particular threshold due to a higher standard-level. As described in Chapter 5 (Section 5.2.4.4, *LCC Results based on ±2% Threshold*), only those consumers with net LCC savings or costs beyond 2% of the baseline LCC are considered to incur substantial impacts due to an increase in the standard. Table L.3.12 summarizes the baseline LCCs for the three TTW units analyzed and also provides the 2% threshold at which consumers are considered to be impacted by a standard-level.

Table L.3.12 TTW Unit Baseline Life-Cycle Costs and Threshold for Significant Impacts

Unit	Baseline Life-Cycle Cost	Threshold for Adverse Impacts: 2% of Baseline LCC
SAC 1.5 Ton	$4,576	$92
SAC 2.5 Ton	$4,867	$97
PAC	$6,001	$120

Tables L.3.13 through L.3.15 and Figures L.3.1 through L.3.6 depict the LCC results for the three TTW units analyzed based on the above defined 2% threshold. The tables show the average LCC values for the baseline level (10 SEER) and the various standard-levels analyzed. As presented earlier in Tables L.3.9 through L.3.11, Tables L.3.13 through L.3.15 also provide for each TTW unit the difference in LCC at each standard-level relative to the baseline. The differences represent either an LCC savings or an LCC cost increase. In addition, each table shows the subset of consumers at each standard-level who are impacted in one of three ways: 1) consumers who achieve net LCC savings greater than 2% of the baseline LCC, 2) consumers who fall within ±2% of the baseline LCC, or 3) consumers who achieve a net LCC increase exceeding 2% of the baseline LCC. Accompanying each percentage value is the average LCC savings or increase that corresponds to each subset of consumers. For example, in the case of the 10.2 SEER standard-level for SAC 1.5 Ton (Table L.3.13), the percentage of consumers with net savings beyond the 2% threshold is 1% and the corresponding average LCC savings for those consumers is $112.

For each product class, two figures are presented; one showing the mean LCC by standard-level and the other showing the percentage of consumers for each standard-level that fall within the three consumer subsets. For the figure presenting the percentage of consumers within each of the three consumer subsets, the corresponding average LCC savings or increase is also presented.

Table L.3.13 LCC Results for SAC 1.5 Ton TTW Units

SEER	Average LCC	Average LCC (Savings) Costs	Percent of consumers with					
			Net Savings (>2%)	Avg LCC (Save) Cost	Impacts within ±2% Threshold	Avg LCC (Save) Cost	Net Costs (>2%)	Avg LCC (Save) Cost
10	$4,576	-	-	-	-	-	-	-
10.2	$4,559	($17)	1%	($112)	99%	($16)	0%	$0
10.5	$4,534	($42)	14%	($150)	86%	($25)	0%	$0
10.9	$4,561	($15)	15%	($188)	85%	$14	0%	$0
11.2	$4,638	$62	9%	($217)	44%	$33	47%	$140

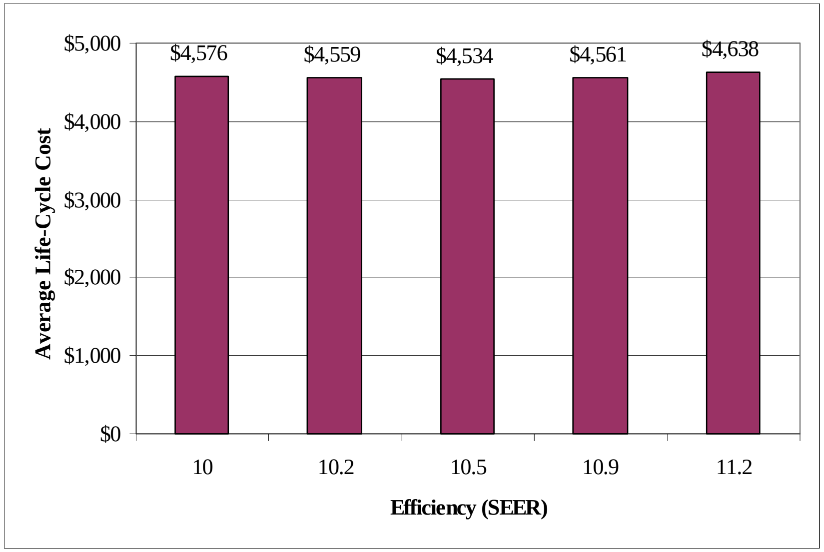

Figure L.3.1 Average LCCs for SAC 1.5 Ton TTW Units

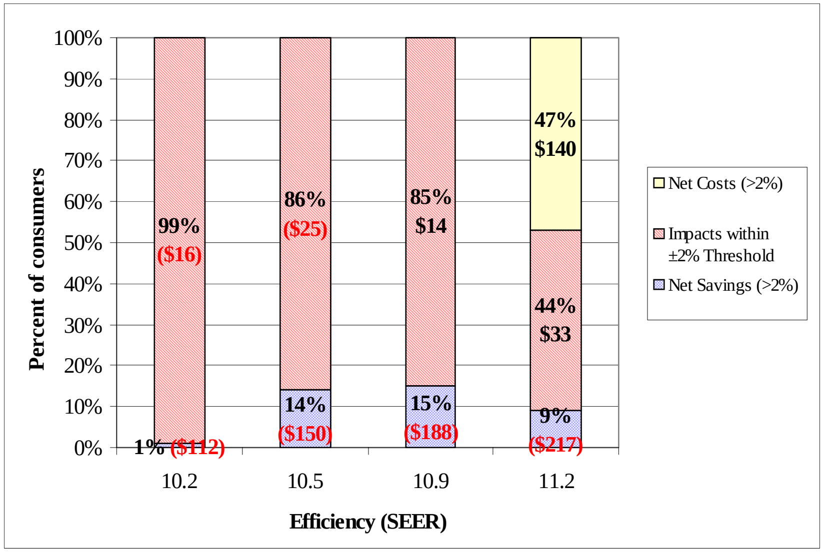

Figure L.3.2 Percent of SAC 1.5 Ton TTW Unit Consumers with Net Costs, Impacts within ±2% Thresholds, and Net Savings

Table L.3.14 LCC Results for SAC 2.5 Ton TTW Units

SEER	Average LCC	Average LCC (Savings) Costs	Percent of consumers with Net Savings (>2%)	Avg LCC (Save) Cost	Impacts within ±2% Threshold	Avg LCC (Save) Cost	Net Costs (>2%)	Avg LCC (Save) Cost
10	$4,867	-	-	-	-	-	-	-
10.3	$4,838	($29)	4%	($135)	96%	($24)	0%	$0
10.5	$4,830	($37)	11%	($153)	89%	($23)	0%	$0
10.9	$4,866	($1)	11%	($192)	87%	$21	2%	$106
11.4	$4,858	($9)	17%	($236)	70%	$23	13%	$116

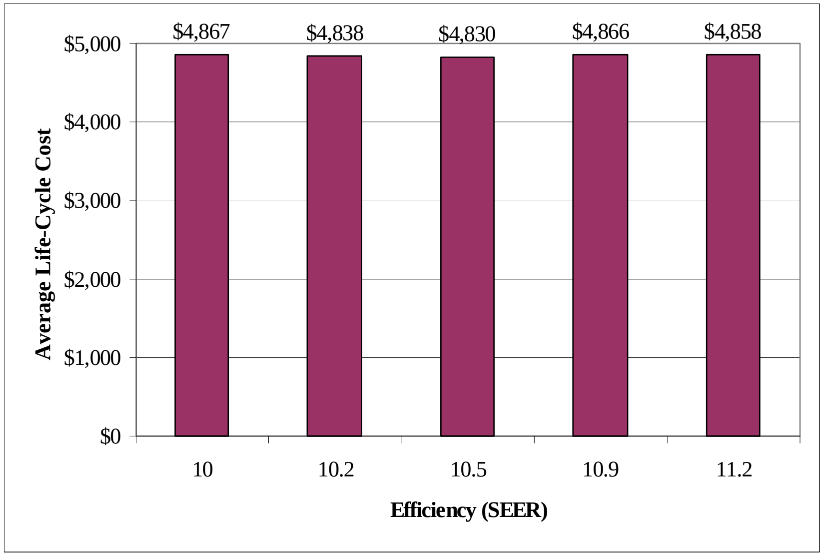

Figure L.3.3 Average LCCs for SAC 2.5 Ton TTW Units

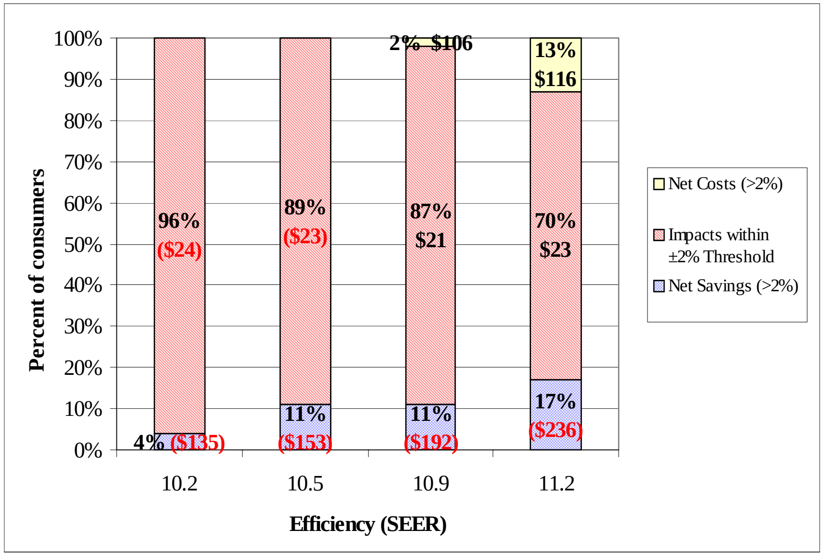

Figure L.3.4 Percent of SAC 2.5 Ton TTW Unit Consumers with Net Costs, Impacts within ±2% Threshold, and Net Savings

Table L.3.15 LCC Results for PAC TTW Units

SEER	Average LCC	Average LCC (Savings) Costs	Percent of consumers with Net Savings (>2%)	Avg LCC (Save) Cost	Impacts within ±2% Threshold	Avg LCC (Save) Cost	Net Costs (>2%)	Avg LCC (Save) Cost
9.7	$6,001	-	-	-	-	-	-	-
9.8	$5,986	($15)	0%	$0	100%	($15)	0%	$0
10.2	$6,004	$3	4%	($177)	96%	$10	0%	$0
10.4	$6,007	$6	6%	($204)	94%	$20	0%	$0
10.6	$6,053	$52	5%	($228)	78%	$51	17%	$140

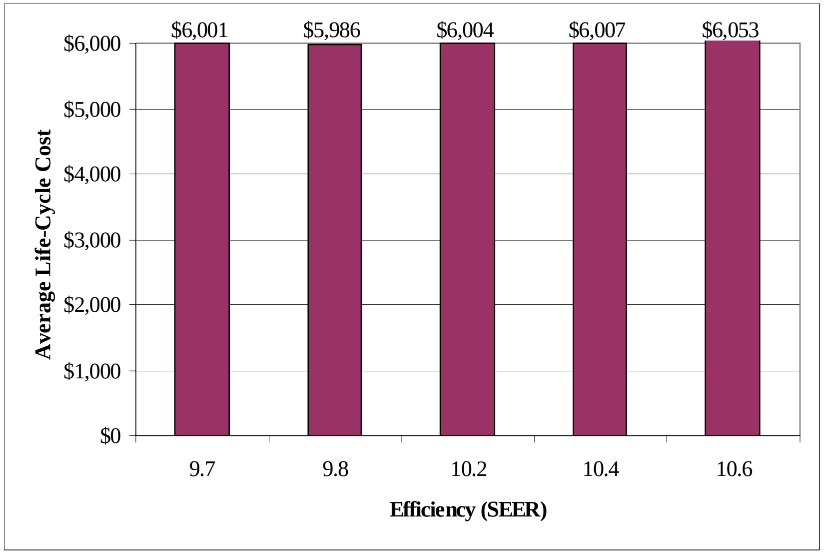

Figure L.3.5 Average LCCs for PAC TTW Units

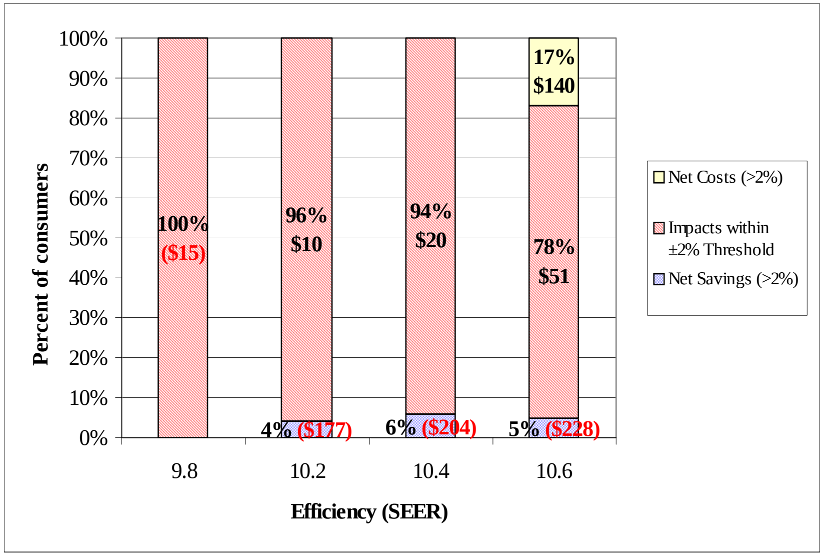

Figure L.3.6 Percent of PAC TTW Unit Consumers with Net Costs, Impacts within ±2% Threshold, and Net Savings